

20th RD50 Workshop

Annealing behavior of 24 GeV/c n-on-p sensors, studied with Edge-TCT and CCE

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Outline

- Motivation of the study
- Samples and irradiation
 - SIMS and Spreading Resistivity measurements
- Edge-TCT measurements
- Preliminary CCE annealing study with Alibava
- Determination of absolute drift velocities in irradiated sensors
- Case studies for two drift velocities curves
- Potential developments (trapping time extraction)
- Conclusions

Motivation

- This work represents the continuation of what already shown at the last RD50 workshop – Edge-TCT annealing study on p-bulk Float Zone and MCz irradiated with 24 GeV/c protons
- New developments are going to be shown in the next slides, namely:
 - Resume on the new absolute drift velocity extraction method from Edge-TCT measurements
 - SIMS and spreading resistance measurements on studied samples
 - Preliminary Alibava (beta CCE) measurements on the irradiated sensors
 - Observation of correlations between results obtained with Alibava and Edge-TCT

Samples and irradiation

DETECTORS:

- 2010 Micron RD50 Production
- Detectors characterized: FZ n-on-p, MCz n-on-p, ministrip geometry
 - 80 μm strip pitch
 - 20 μm strip width

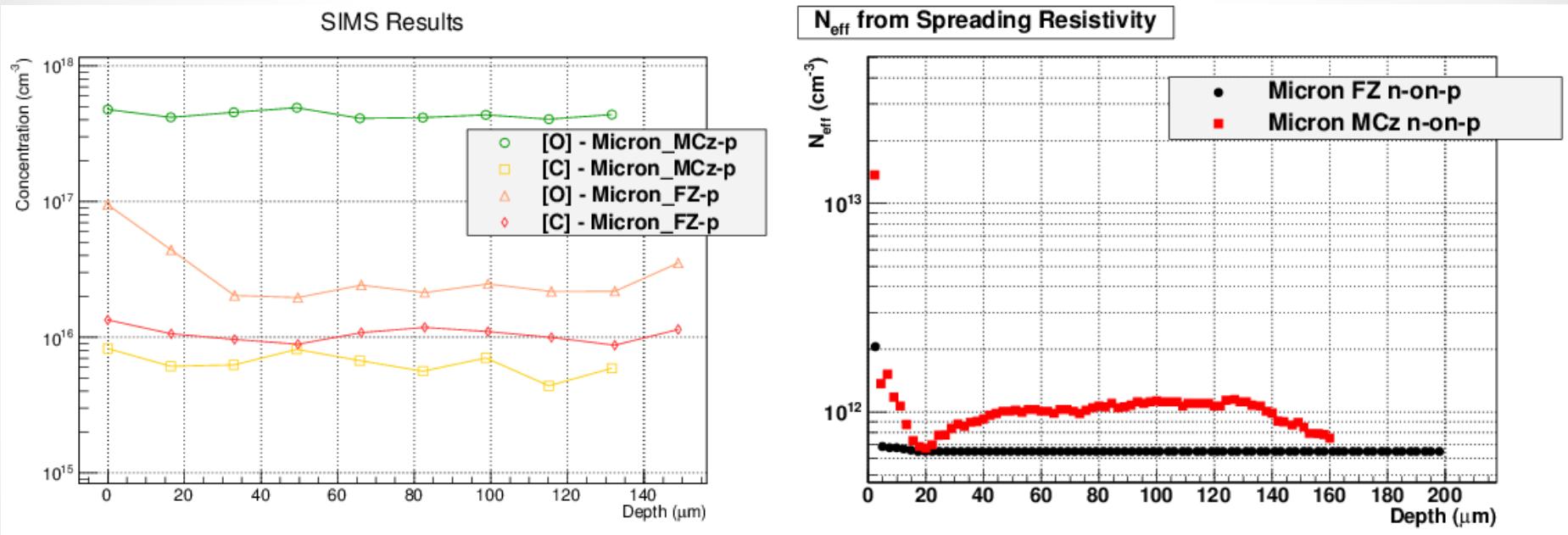
IRRADIATION:

- Irradiated at CERN PS with 24 GeV/c protons in P1-2011
- Irradiation fluence: $1 \cdot 10^{16} \text{ p/cm}^2$ ($6.1 \cdot 10^{15} \text{ n}_{\text{eq}}/\text{cm}^2$)

MEASUREMENTS:

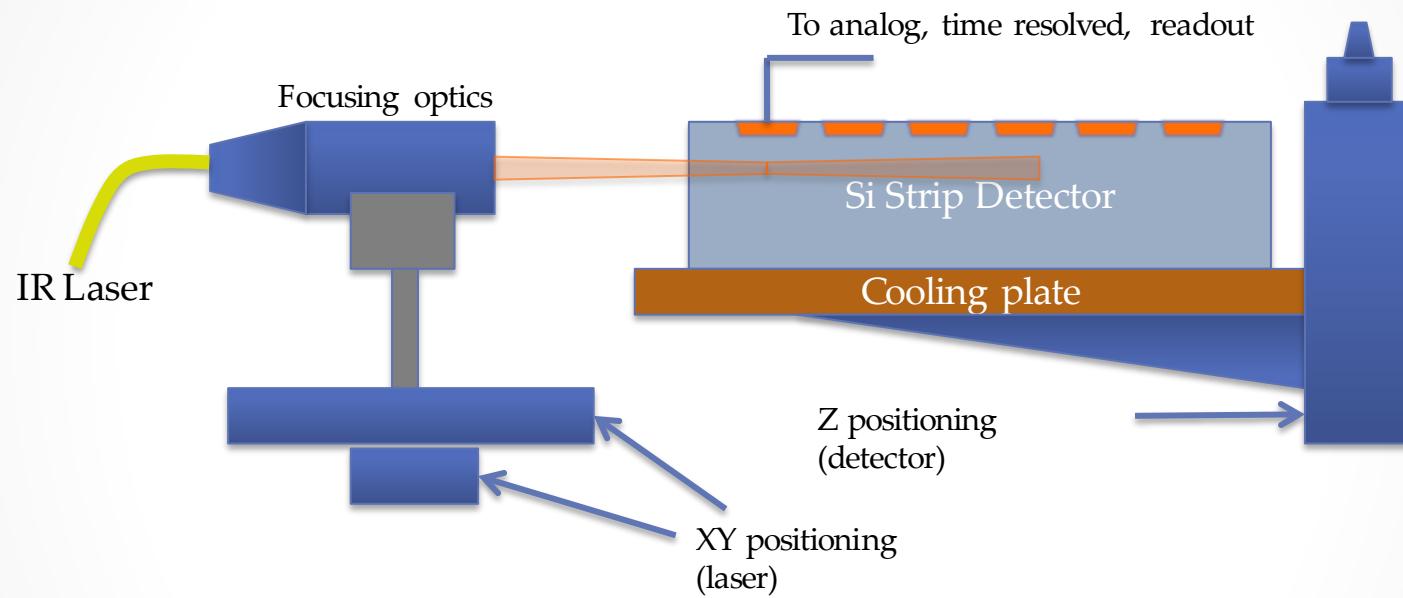
- All measurements were performed at -25°C
- Highly irradiated detectors required low cluster charge cuts: Seed 3, Neigh. 1.5

SIMS and Spreading Resistivity measurements

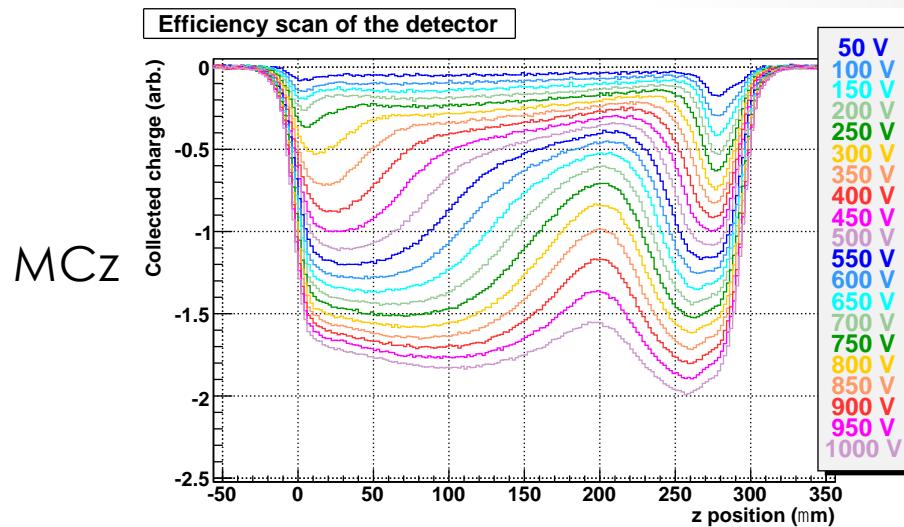
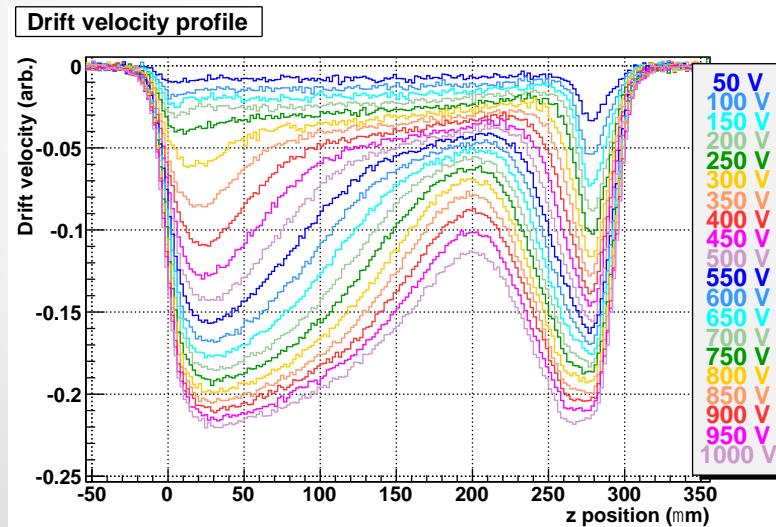
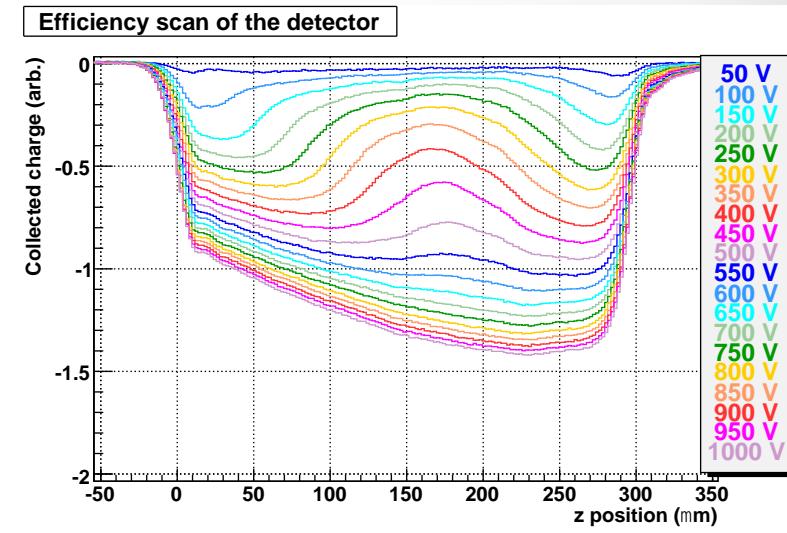
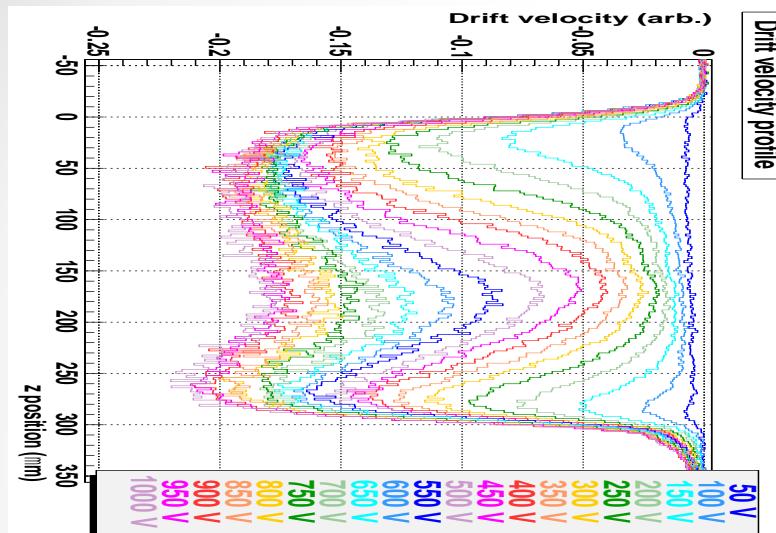


SIMS and Spreading resistance measurements performed at ITME.
~x 10 difference in oxygen concentration in favor of MCz

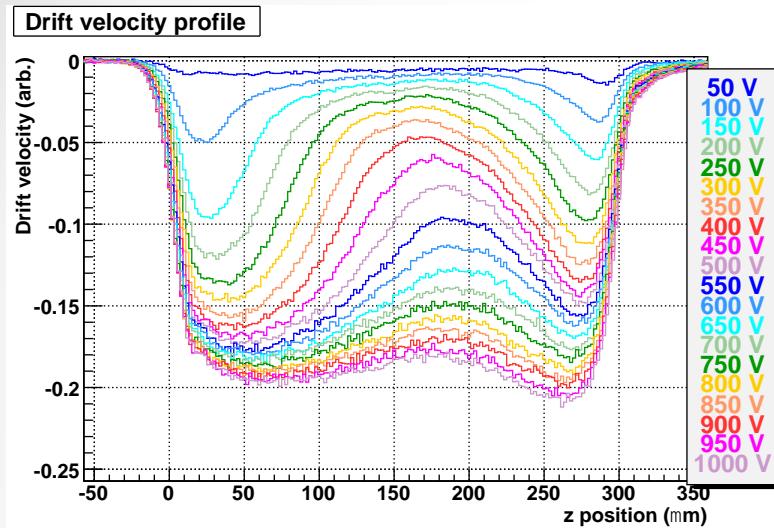
Edge-TCT setup



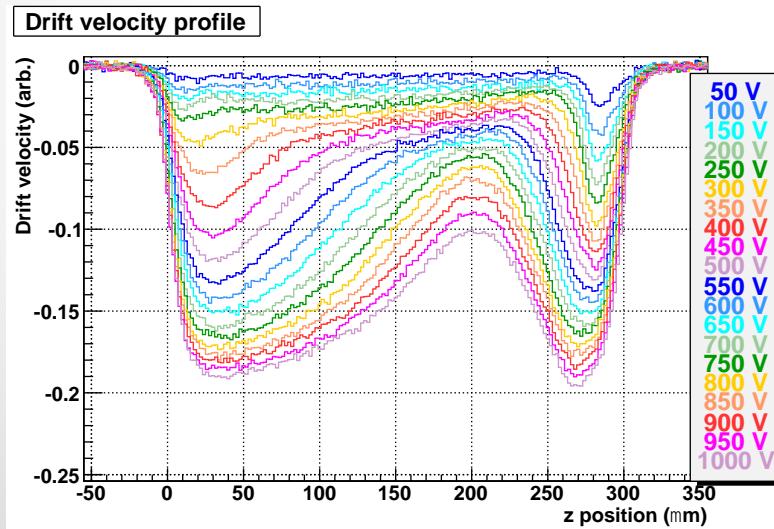
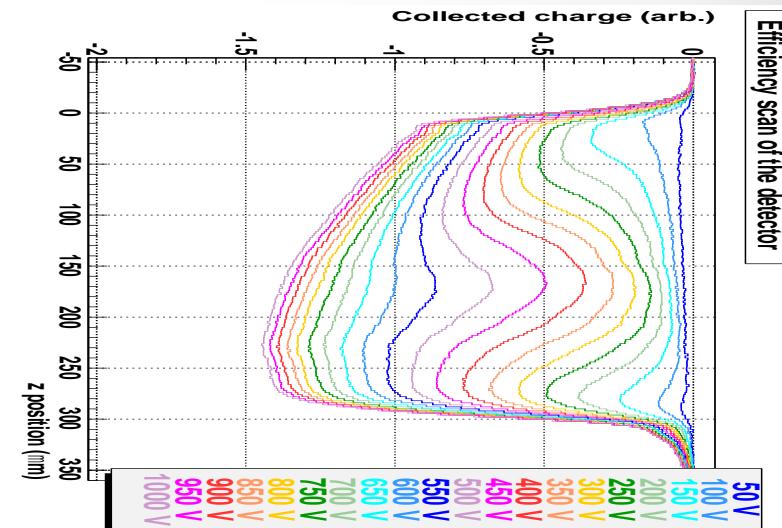
ETCT – no annealing



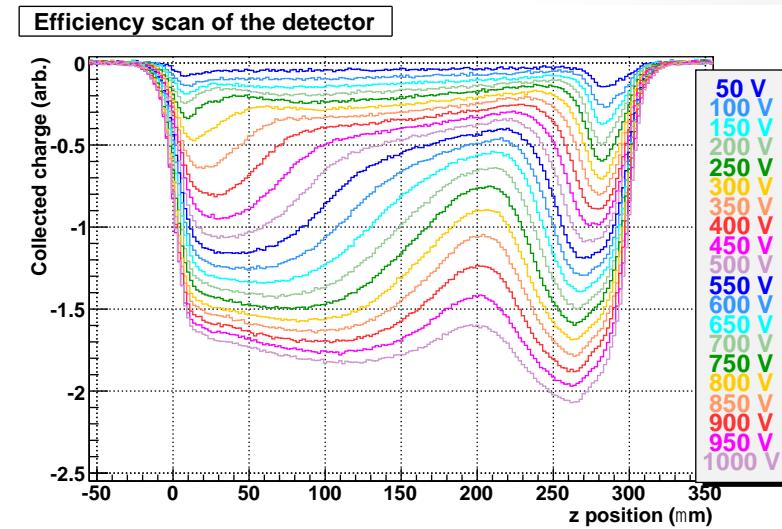
ETCT- 80 mins ann.



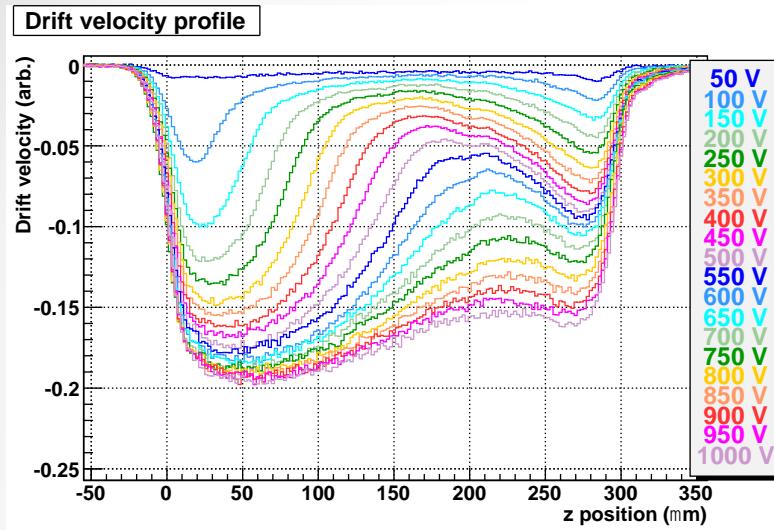
FZ



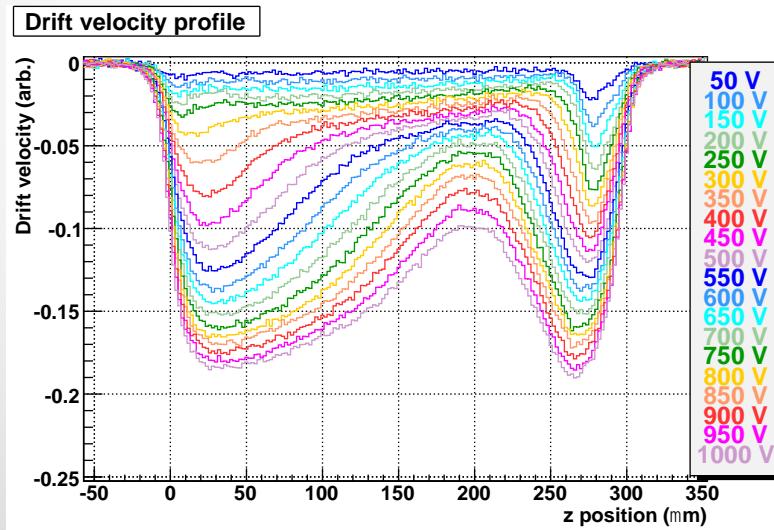
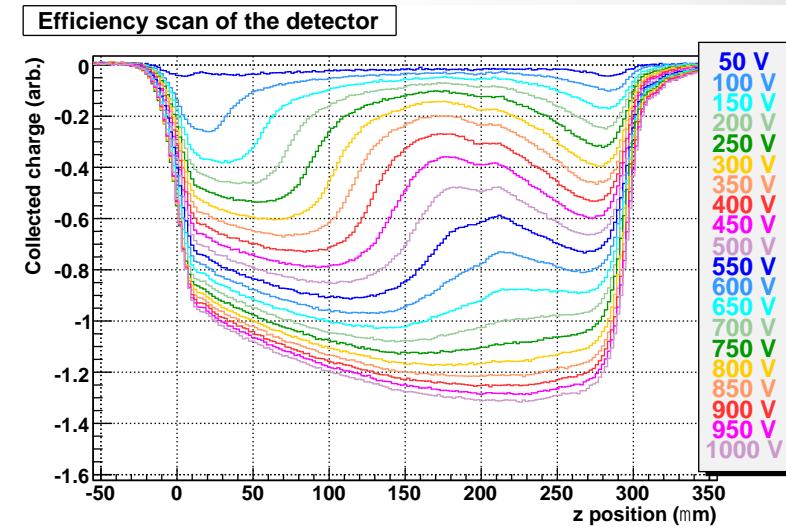
MCZ



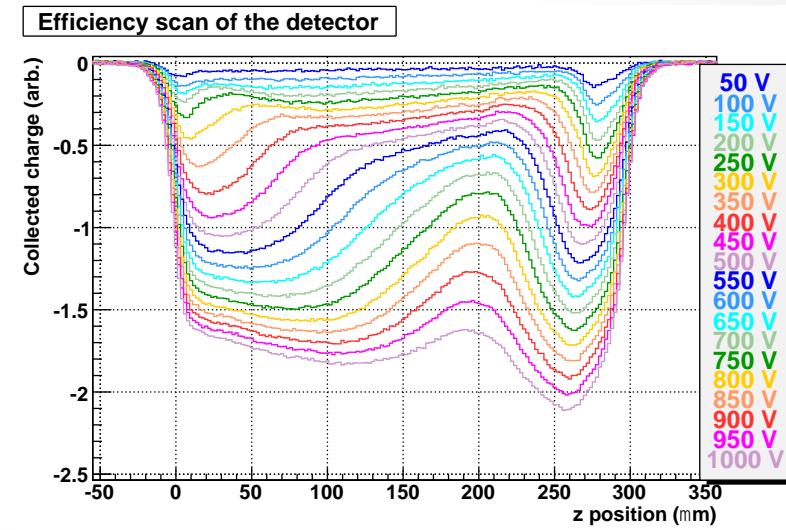
ETCT – 240 mins ann.



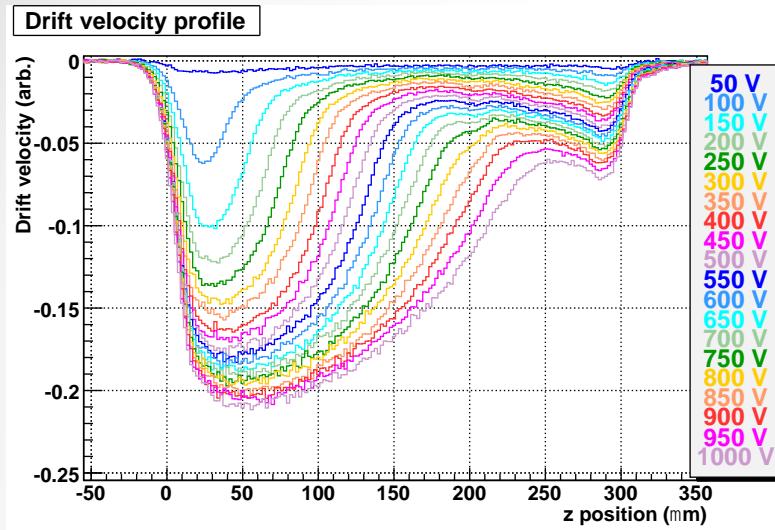
FZ



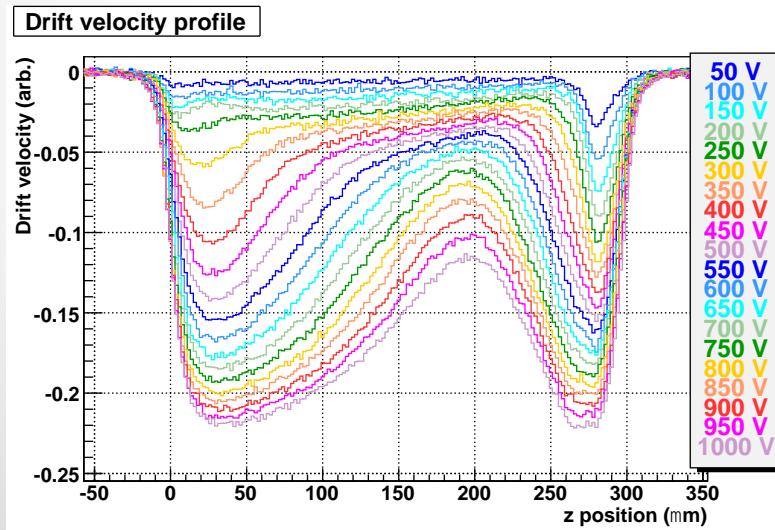
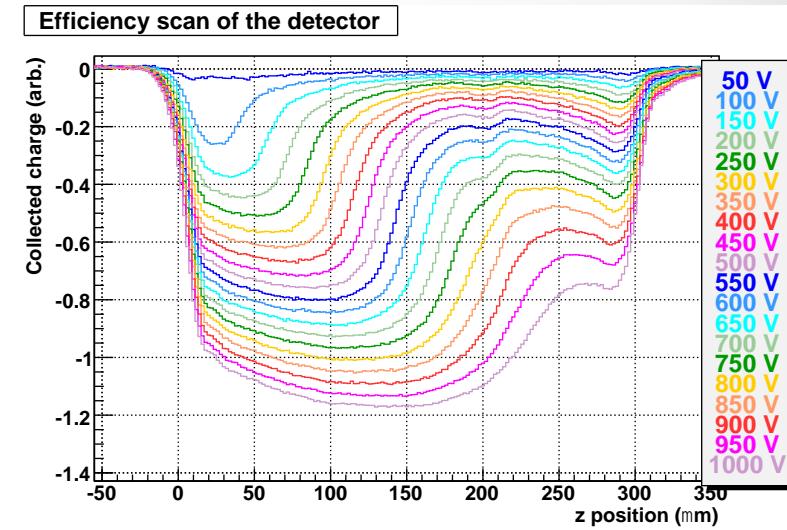
MCZ



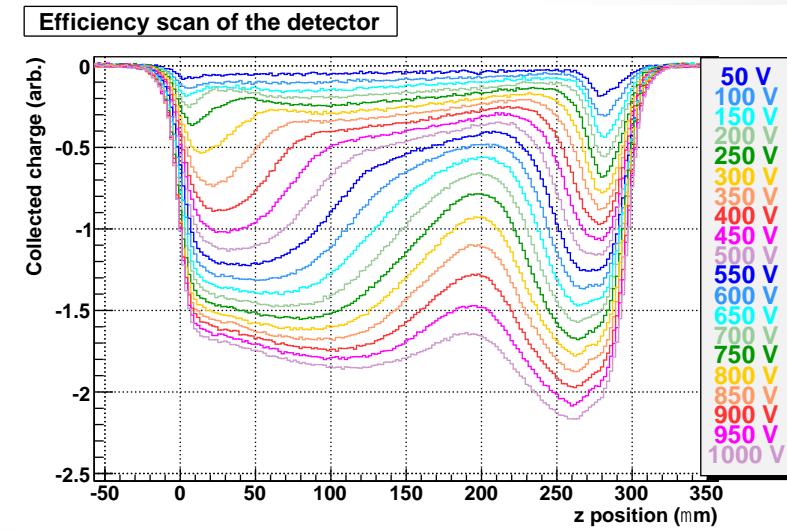
ETCT – 560 mins ann.



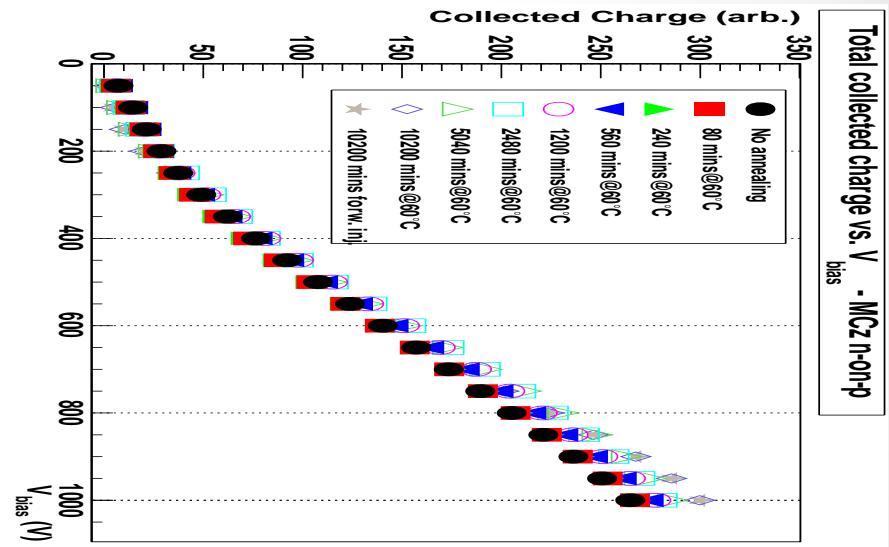
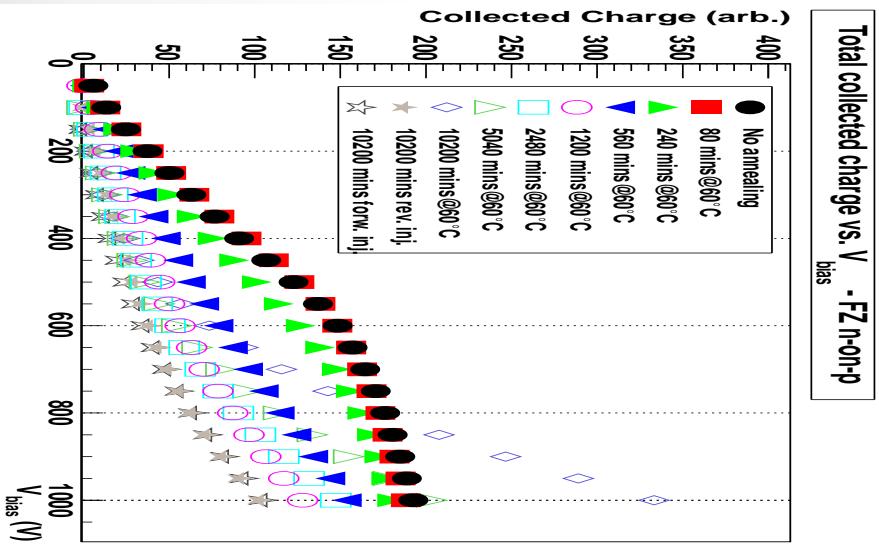
FZ



MCZ

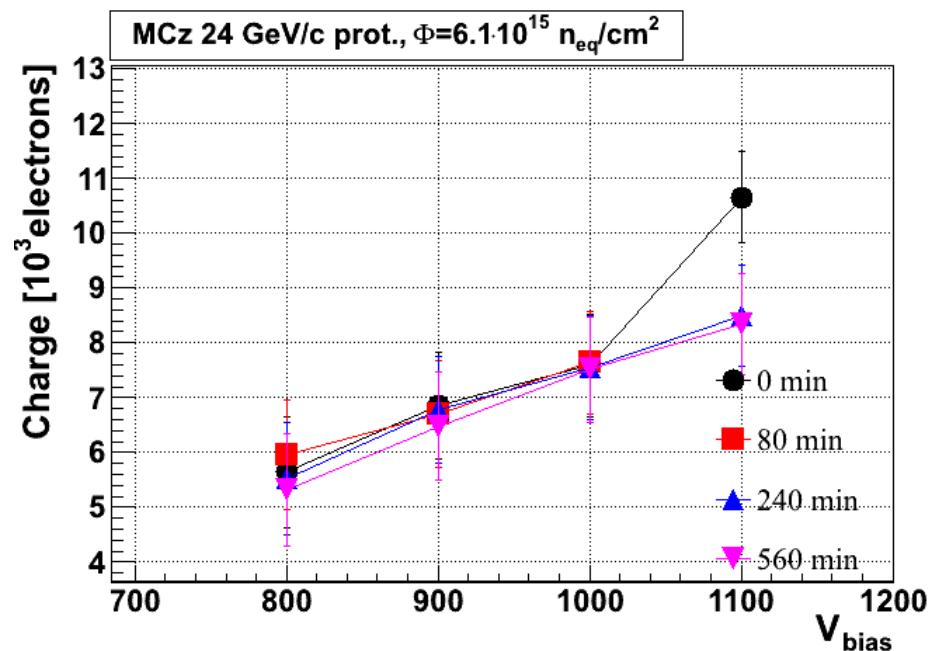
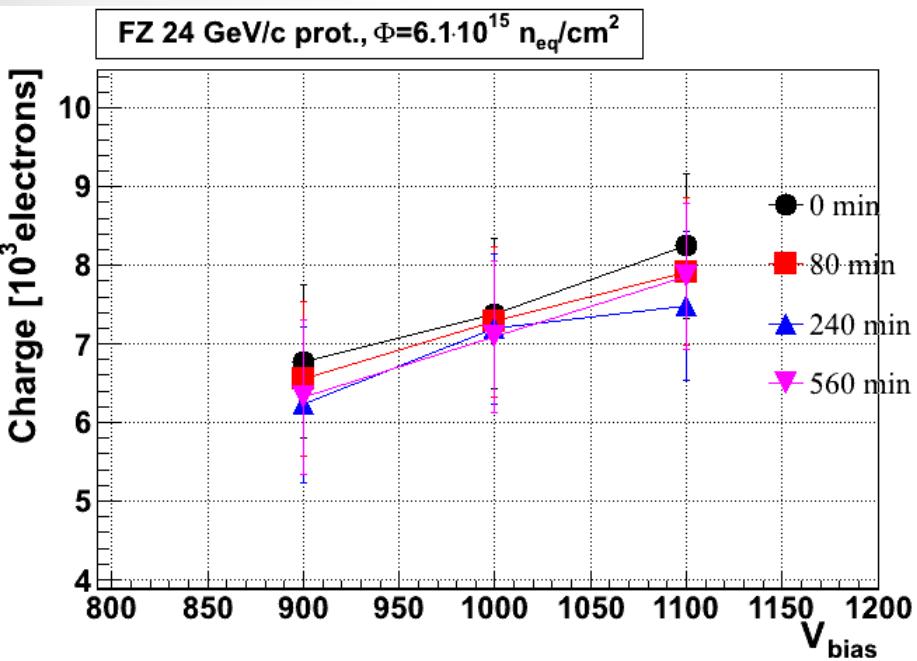


Total collected charge efficiency, as a function of annealing time



- Total collected charge shows almost no dependence from annealing for MCz samples, while a sensible evolution is visible in Float Zone irradiated material – Scales in the two plots can be compared to 20% accuracy (see 19th RD50 workshop presentation – Charge Scaling Method)

CCE with Alibava



Absolute drift velocity values extraction

- Edge-TCT is able to provide us with a nice profile of the “drift velocity” of carriers in the bulk... but what carriers?
- The profile is given by the local sum of the contributions coming from the two types of carriers.
- To this we should add the smearing provided to the profile by the width of the gaussian laser (~5 to ~8 um, depending from how lucky we are)
- It is nice to have “units of measure” on the axis...

Absolute drift velocity values extraction

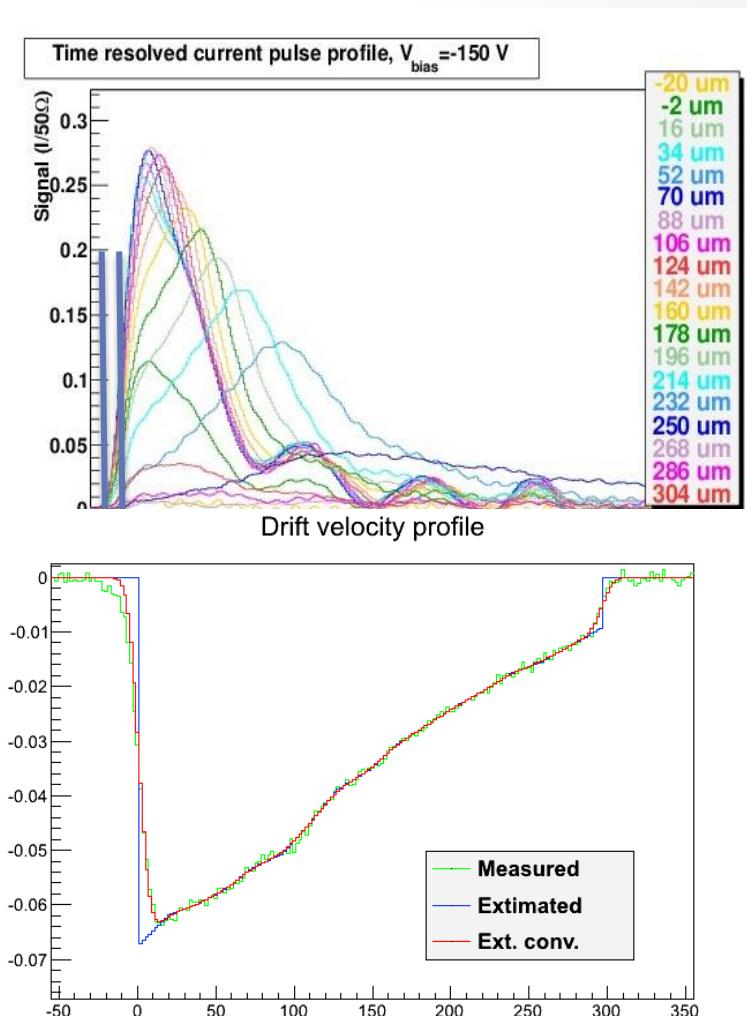
Integration over the rising edge provides information localized at the injection depth. For irradiated sensors this information is still basically unaffected by trapping:

$$i_0 = n \times e_0 \times v(x)$$

initial current Drift velocity at injection site

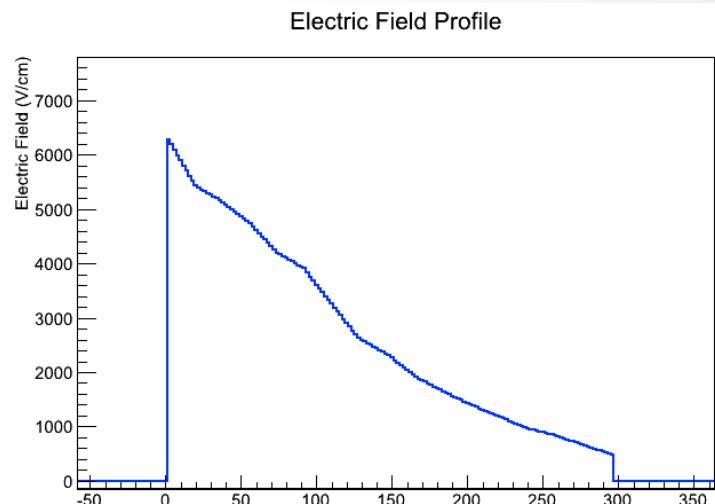
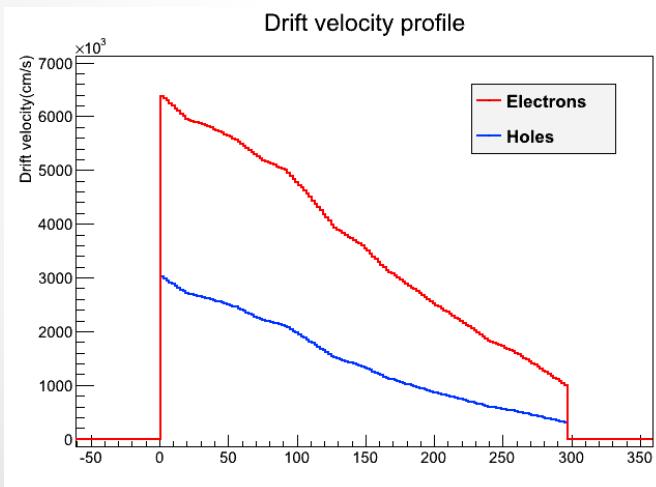
The so-obtained drift velocity profile is convolved with the laser profile (gaussian) though, and is in fact the sum of the drift velocities of electrons and holes.

Deconvolution is obtained by bisection method, looking for the best profile (approximated by a polygonal) that once convoluted with the gaussian beam gives the measured one.



Absolute drift velocity values extraction

Next, again by bisection, electric field is obtained from drift velocity – imposing as boundary condition the applied bias voltage and *exploiting the fact that complete saturation only happens with really high fields.*



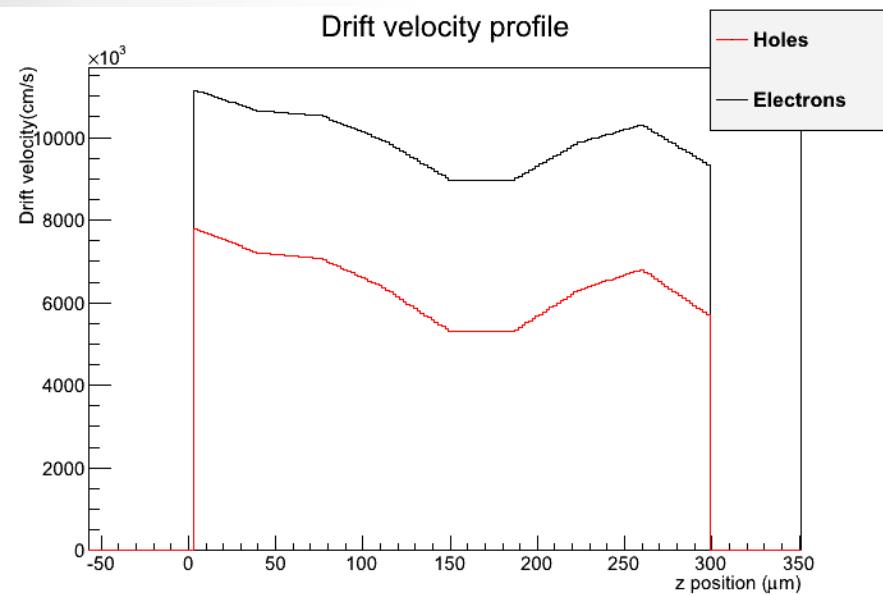
From this we can easily revert to the drift velocities for holes and electrons within the bulk...



Comparison of collected charge values to E-TCT

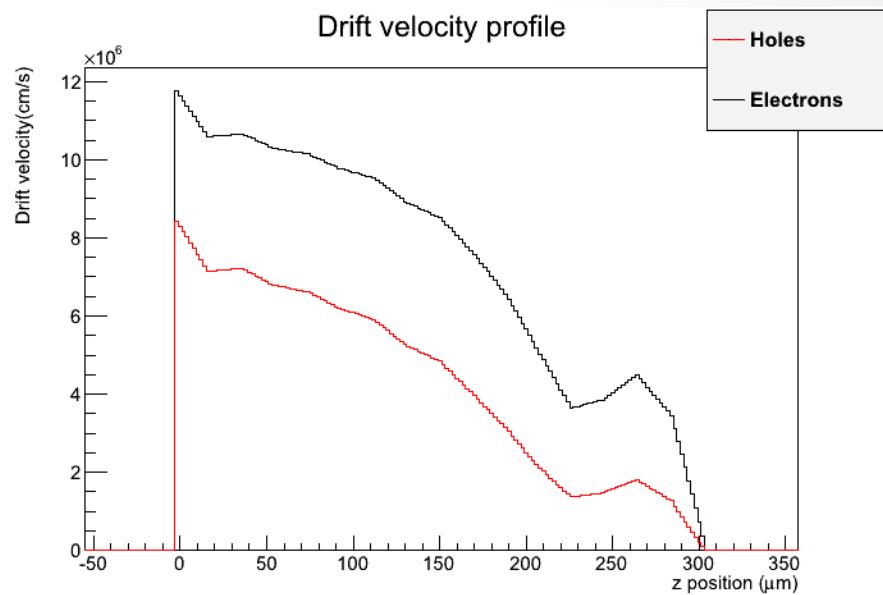
FZ, 1000 V

@ 0 minutes
annealing



~7400 e⁻

@ 560 minutes
annealing

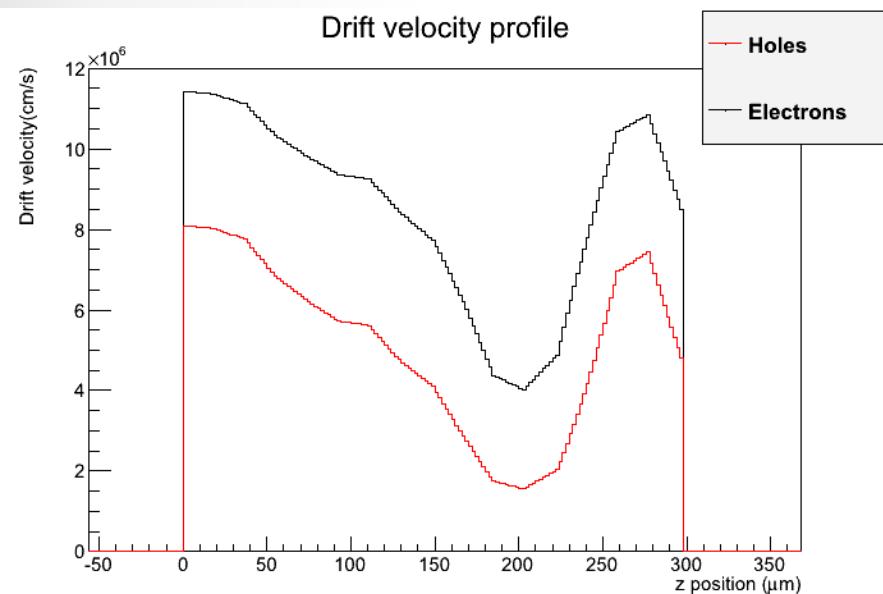


~7100 e⁻

Comparison of collected charge values to E-TCT

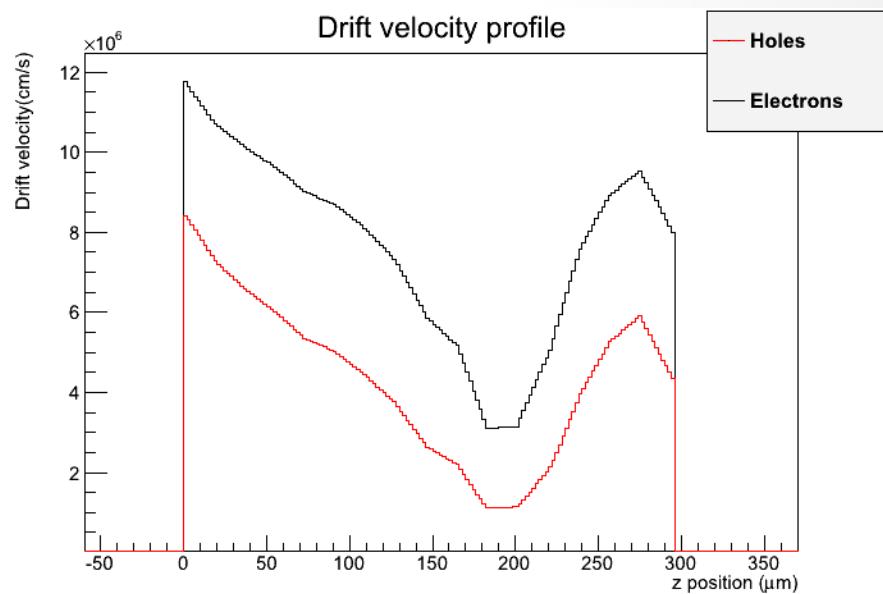
MCz, 1000 V

@ 0 minutes
annealing



$\sim 7600 \text{ e}^-$

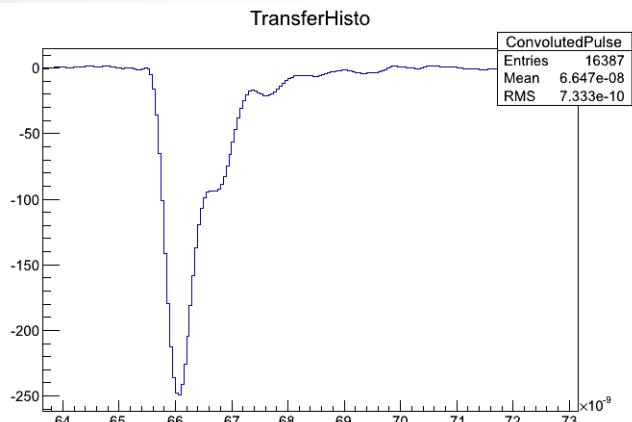
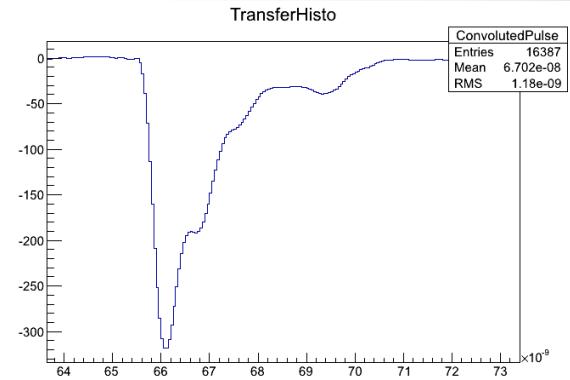
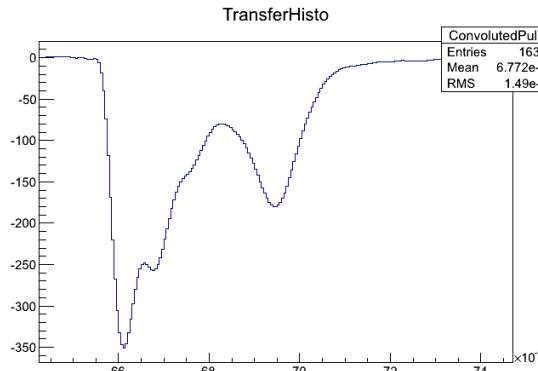
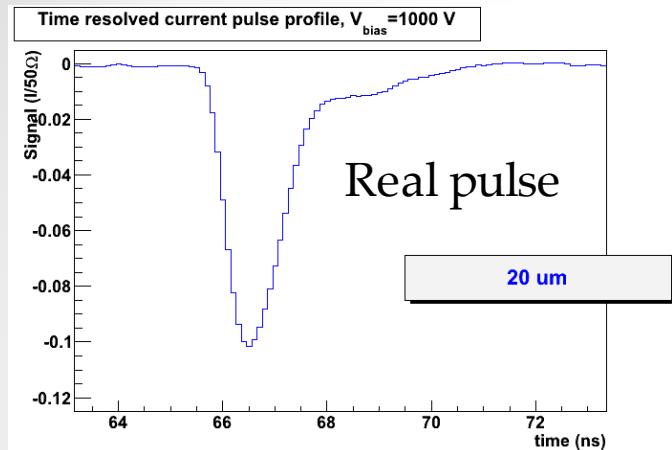
@ 560 minutes
annealing



$\sim 7500 \text{ e}^-$

Case study (Preliminary)

MCz, no annealing, injection 20 um underneath the strip, 1000 V



Simulated, 0.5 ns trapping
integral ~ 490 a.u.

Simulated, no trapping
integral ~ 1820 a.u.

Simulated, 2 ns trap.
integral ~ 1000 a.u.

- Second peak totally disappears at trapping times in the order of 0.5 ns
- It's interesting to notice that 0.5 ns trapping only marginally affects the rising edge – Proves Edge-TCT to be reliable for drift velocity extimation even at very high fluences
- More efforts are needed on transfer function extimation, to have extremely precise trapping time measurements (i.e. either use a network analyzer or a proper circuit simulation)

Conclusions

- Preliminary Alibava measurements show a good correlation between the evolution of collected cluster charge and field development.
- Lower values for MCz silicon have to be justified by the fact that the field developing close to the back region is “less useful” than the one developing from the front side region
- Active volume is still deeper than expected from standard Hamburg model with the rule of thumb of $\sim 150V/1e14 n_{eq}/cm^2$, V_{dep} should be in the order of 6,000 V, hence at 1000 V only $1/\sqrt{6}$ or the thickness (~ 120 μm) should be depleted. This is clearly not the case at least for the FZ detector.
- The even field in the bulk can justify high charge collection efficiency results even without charge multiplication (that comes into play at later annealing stages, as seen in previous workshop presentation)

Thank you...